ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 67 (2013) 70 – 77

Procedia Engineering

www.elsevier.com/locate/procedia

7th Asian-Pacific Conference on Aerospace Technology and Science, 7th APCATS 2013

Prediction of Commercial Aircraft Price using the COC & Aircraft Design Factors

D. I. Lee[a,]*, W. Jin[b]

[a]*Marketing & Business Development Strategy Team, Korean Air – Aerospace division, Busan, South korea*
[b]*Department of Aviation Maintenance Engineering, the Far East University, Chung Chong Buk-Do, South korea*

Abstract

Predicting market price of commercial aircraft is important for the analysis of business profit in the development stage of a new aircraft program. Although many factors have been significantly considered, it is difficult to predict the accurate aircraft price because of the uncertainty and many considering factors in the real market.
In this study, the price prediction method to assess the value of a new aircraft was based on a comparative approach for the aircraft performance and design factors. Through applying this method, the COC was considered as a key factor because it becomes to be crucial for an airliner's profit due to the recent aviation fuel price rising. In summary, the COC sensitivity analysis was performed using aircraft design factors to see how engineering values and aircraft price were closely related each other.

Selection and peer-review under responsibility of the National Chiao Tung University

Keywords: Aircraft Price Prediction, COC(Cash operating cost), COC Sensitivity Analysis, Profit Analysis, Aircraft Performance

1. Introduction

Predicting market price of commercial aircraft is important for the analysis of business profit factors, such as IRR(Internal Rate of Return) and EBIT(Earnings before Interest and Taxes) in the development stage of a new aircraft program. The prediction of the accurate aircraft price, however, is difficult because of the future market uncertainty and various factors, which might be changed under the effects of the market environments, such as the COC (Cash Operating Cost), and aircraft design factors, such as configuration and size, performance, engine type, commonality with baseline aircraft, reliability, etc.

* Corresponding author. Tel.: +82-51-970-6967; fax: +82-51-970-5060.
E-mail address: dilee@koreanair.com

Selection and peer-review under responsibility of the National Chiao Tung University
doi:10.1016/j.proeng.2013.12.006

In this study, we utilized an approach methodology that focused on how aircraft price and design factor could be influenced each other in terms of the market environment, supply and demand, orders, and favorable performance for airliner.

The study of price prediction was performed in two steps: the Phase One was the prediction of aircraft price by modeling of two parameters – the COC and price of various existing competitive aircraft. In the Phase Two, a sensitivity study of design factors was performed to analyze relation by performance analysis. The aircraft for this study, called as 'D,' was a turboprop airliner with over 90-seating capacity.

2. Terminology Definition

In this study, the standard terminologies for predicting aircraft price are Base Value, Baseline and Potential Value. The definitions and concepts of terminologies are coincide with the AVITAS values.[1]

- Base Value: is an economic and reasonable price of an aircraft in current market environment between seller and buyer under the balance of supply and demand.
- Baseline: is a liner regression of selected basis values as a function of cabin seats. For example, the new aircraft was compared to existing competitive aircraft with similar size in terms of seat numbers and comfort levels. The comfort levels could be defined by cabin noise and vibration level, cabin & seat comfort, etc. After selecting competitive aircraft, the basis values of competitive aircraft by market analysis is determined and then establish a slope for the linear regression of competitive aircraft.
- Customer Factor: is a factor that customer (airline) mainly consider when they have a plan to buy aircraft. According to the market survey, the customer favorable factors, such as the COC, speed, noise, maintenances cost can be listed up in order. These factors can be main strategy of design philosophy in the early stage of aircraft development.
- Potential Value: is a value that new aircraft have potential benefits (or dis-benefits) of customer factors compared to existing competitive aircraft. If benefit can be expected, it would be a premium value. If not, it would be called a discount value. For example, potential value is estimated by present value method for customer factor(s) of annual savings between new and existing aircraft. This value is calculated by present value of customer factors of annual savings between new and existing aircraft.

3. Phase One: Aircraft Price Prediction

The aircraft price prediction method to assess the price of a new commercial aircraft is based on a comparative approach which compares the new aircraft to similarly-sized existing aircraft in the marketplace. New aircraft price consists of the Base Value and Potential Value as shown Eqn. (1). Base Aircraft Value can be calculated from the existing competitive aircraft price as function of Seating Capacity as shown Eqn. (2). And Potential Value can be estimated by customer factor and associated Risk Factor as shown Eqn. (3).

$$\text{New Aircraft Price} = \text{Base Aircraft Value}^{*1} + \text{Potential Value}^{*2} \tag{1}$$

$$^{*1}\text{: Base Aircraft Value} = \text{Base Aircraft per Seat} \times \text{New Aircraft Seating Capacity} \tag{2}$$

$$^{*2}\text{: Potential Value} = \text{Additional New Aircraft Value} \times \text{Risk Factor} \tag{3}$$

First of all, the base aircraft should be determined by comparing existing competitive aircraft by means of criteria of seat numbers and comfort levels. The comfort levels could be defined by cabin noise and vibration level, cabin & seat comfort, etc. Then, base values of competitive aircrafts would be investigated by the market analysis. Second, the baseline from those of base values is modeled by linear regression as a function of cabin seats. The considering aircraft in this study, D, has about 90 to 100 seats with turboprop engines. Therefore existing competitive aircraft can be ATR42/72, Q400, CRJ700/900, and E170/175. From these candidates, the Base Value and Baseline of new aircraft can be induced as shown Fig. 1. In this study, Q400 is assumed to be the Base aircraft and slope of the Baseline is obtained by linear regression of each competitive aircraft. Then, Base Aircraft Value can be estimated as function of seating capacity.

Potential Value consists of Additional Value of new aircraft and Risk Factor as shown Eqn.(3). Additional Value can be induced by customer factor, throughout market surveys, instead of a sales strategy of new aircraft. From our market survey, the COC is found to be a main factor among the customer factors since airliners are willing to consider purchasing new aircraft to save the cost for fuel and labor. As a result, the Additional New Aircraft Value can be calculated as function of COC savings. The COC as customer factor can be replaced with other factor(s) such as flight speed, DMC (direct maintenance cost) and so with respect to market circumstance and design philosophy. In detail, the Additional Value can be calculated from the present value of annular COC savings, at a discount rate of 10%, for a 10 year period. These constants have been assumed to be the risk associated with the development of derivative of D, or the introduction of a new manufacturer and the integration of all the new upgrades. Half of this value is then added to the Baseline to establish the Potential Value of new aircraft. Only half the amount is added to the aircraft value because it is assumed that the manufacturer and customer will share the savings equally in the upside of the new aircraft. As above reasons, the Risk Factor is assumed to be 0.5 in terms of benefit share equally between manufacturer and airliner. All procedures of obtaining aircraft price are shown schematically in Fig. 1. In this case, the D has attributes that warrant a premium value to the established Baseline because D has a conceptual configuration of more enhanced COC parameter than Q400.

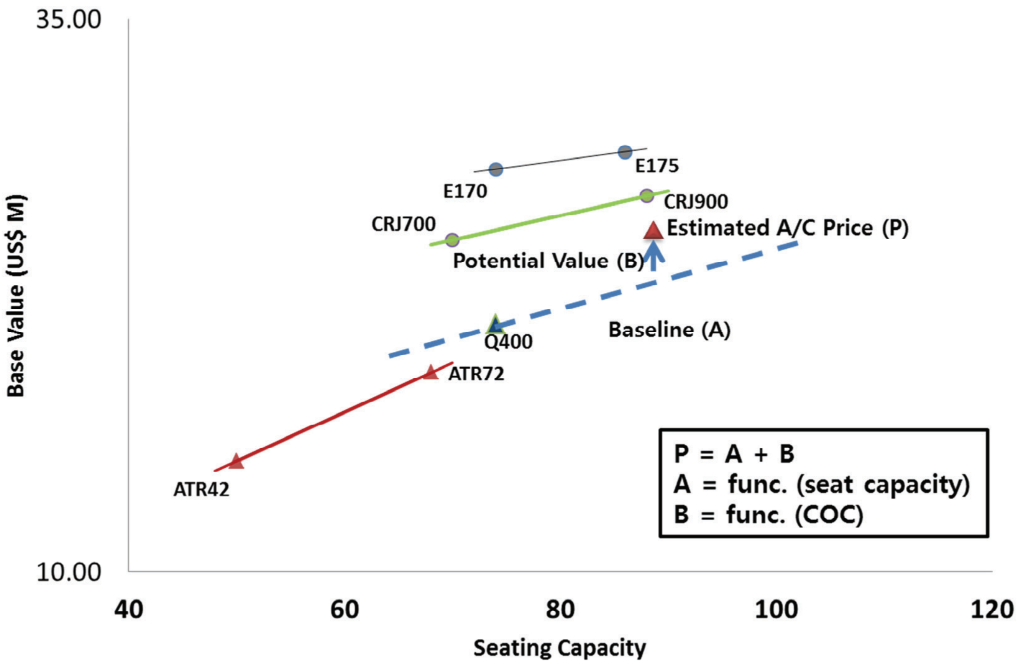


Fig. 1: Schematic of Base Value of new aircraft

4. Phase Two: Engineering modeling

In the Phase One, the COC as key factor of predicting price is converted to the Potential Value. In the Phase Two, the COC is modeled as perspective of engineering so that a simplified COC equation can be proposed, then the effect of the COC on aircraft price is described through the COC sensitivity analysis.

The COC consists of the following parameters - crew cost, fuel cost, maintenance cost, landing and navigation fee and airplane handling fee as shown Eqn. (4)[2]. For the simplification, the following COC parameters were assumed to be constant; labor costs (crew & cabin), fuel cost, landing and navigation fee, and airplane handling fee. Also labor cost and material cost were considered as constant values. Because these components are not engineering parametric values but artificial values related with economic environment. Thus, the COC equation can be expressed by only function of block fuel, block hour, and operation range to find relation between aircraft price and design factor as shown Eqn.(5).

$$\begin{aligned} \text{COC} = \; & (\text{Crew cost x Block hour}) + (\text{Fuel cost x Block fuel}) + \text{Maintenance cost*3} \\ & + \text{Landing and Navigation fee} + \text{Airplane handling fee} \end{aligned} \tag{4}$$

where, maintenance cost = f {labor cost, material cost, per flight (related operation range), per air hour}

$$\text{Simplified COC} = \text{O} \times f\ \{\text{block fuel, block time, range}\} \tag{5}$$

where, O is constant of operation cost

In the analysis of the COC distribution on D shows result that fuel price is about half of the COC component as shown Fig. 2. In other words, the COC can be improved by optimizing preliminary design value influencing on block fuel, block hour. Because fuel consumption can be adjusted by aircraft configuration and performance related with aircraft design values such as SFC (Specific Fuel Consumption) and aerodynamic performance.

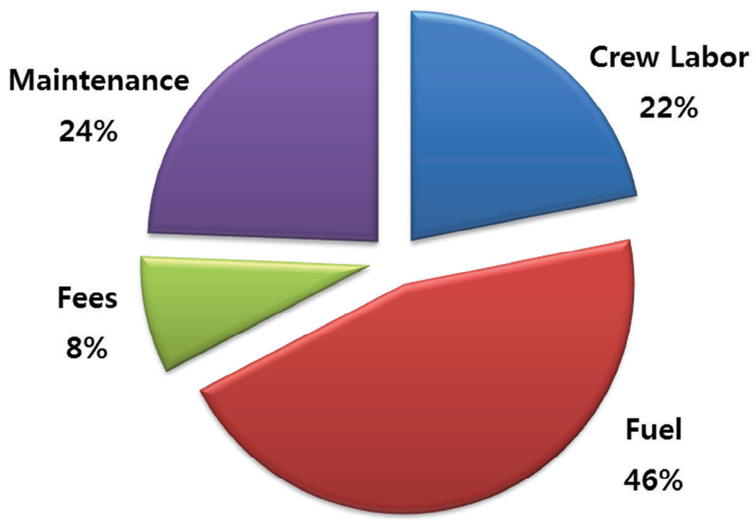


Fig. 2: COC distribution on 500nm

5. Results and Discussions

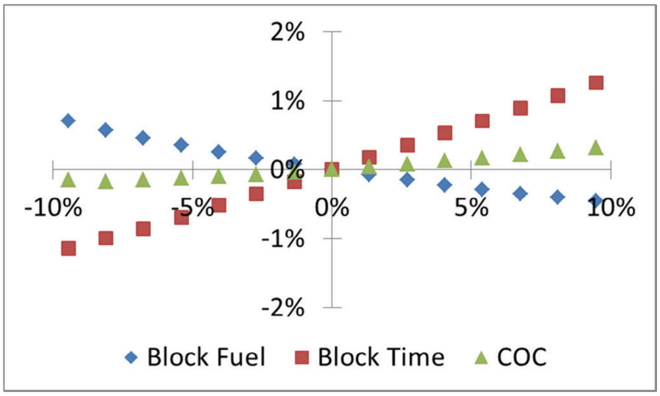
The COC sensitivity study is performed with varying aircraft design factors to investigate influence on aircraft price by performance analysis. First, the effect of SFC changes is researched based on three types of aircrafts - D, advanced D and base aircraft. Q400 was selected as the base aircraft to calculate the base price of the D. The advanced D is assumed 10% better SFC than the D. Table 1 shows the variation of COC savings and potential values of each aircraft. As the result, 10% enhancement of SFC can reduce about 5% of COC/PAX (passenger) comparing D to advanced D. This causes $ 1.7M difference of the Potential Value and 6.2% price up from D price by commercial aircraft price prediction method.

Second, design values such as wing area, aspect ratio, taper ratio and thickness ratio of wing root are researched based on the D configuration. These factors are a key for wing design and overall aircraft performance and are also considered as the optimization values of aircraft design [3].

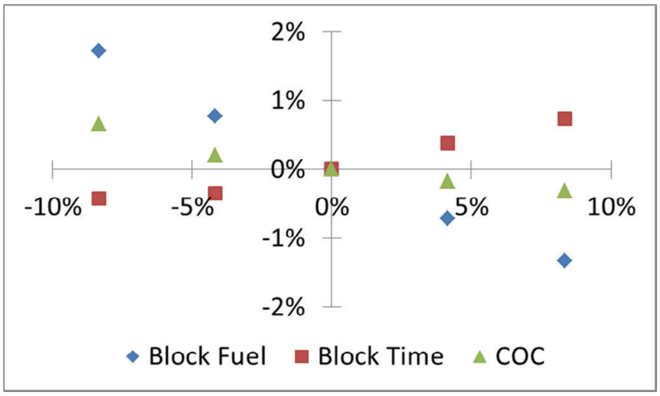
In this study, the COC sensitivities with respect to varying these values are performed. The condition of parametric study is changing wing area, aspect ratio, taper ratio and wing thickness from base configuration under constrained MTOW(Max Take Off Weight) and operational range – 500nm. The result of the COC related changes is shown in Fig. 3. Relative changes of block fuel and time are quite sensitive with the variation of wing area and aspect ratio. The changes of taper ratio and T/C, however, do not cause block fuel and time variation. Among these design values, the COC is mostly influenced on aspect ratio changes about 1% when 10% changes of based design value. But other factors do not cause significant changes because the enhancement of aerodynamic performance should cause negative effect of structural performance. Table 2 shows the result of sensitivity study of the COC between aircraft price and considered design values.

Table 1: Calculation Details on SFC Changes

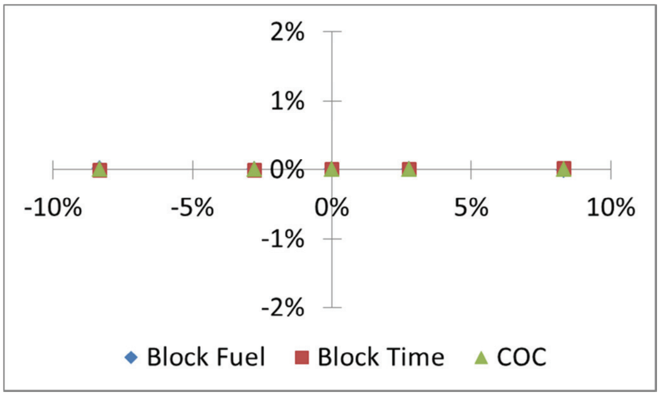
	Base Aircraft	D	Advanced D
COC difference / PAX	Base	10.36	12.09
Trips per year on 500nm	1750		
COC savings($) / PAX	Base	18,130	21,157
Present Value of annual savings ($)		92,046	130,004
Potential value (M$)		**4.1**	**5.8**
Increment Aircraft Price		**Base**	**6.2%**



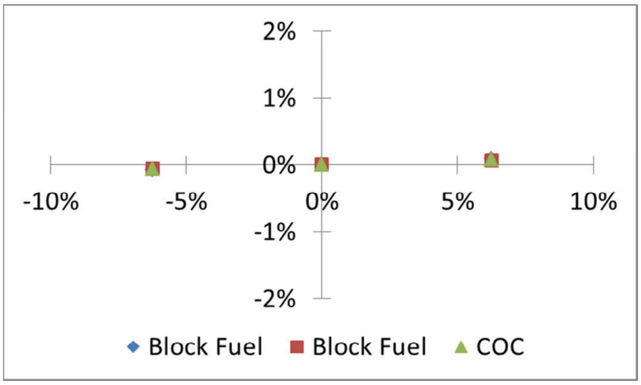
(a) Wing area



(b) Aspect ratio



(c) Taper ratio



(d) T/C – root

Fig. 3: COC relative variation with design values on 500 nm

Table 2: Calculation Details on Design Value Changes

	D	Wing Area	Aspect Ratio	Taper Ratio	T/C - root
Relatives of COC difference (%)	Base	0.2	0.4	Negative	0.1
Potential Value ($)		32,259	75,271		18,818
Relatives of aircraft price difference (%)		0.12	0.27		0.07

6. Conclusion

This study was focused on the approach methodology of commercial aircraft price prediction only using the COC and related design factors: therefore, the result may not enough to suggest general information for the aircraft design. However, this methodology can be useful to estimate a new aircraft price and to determine the design concept in the early stage of an aircraft development project.

Most of the studies of aircraft design have usually been focused on engineering optimization. However, it is also necessary to consider a business perspective in order to succeed in an aircraft development program. From the optimization of aircraft price prediction procedure, more competitive aircraft in the world market will be able to be designed and manufactured.

Acknowledgements

This research was supported and funded by the Korean Ministry of Knowledge Economy, under the program of the Development of Advanced System Technology for Customer-oriented Airliner.

References

[1] Douglas B. Kelly, Forecasting aircraft values: An appraiser’s perspective, Air-finance annual, 2008.

[2] Liebeck, R.H., et. Al., Advanced Subsonic Airplane design and Economic Studies, NASA CR-195443, April 1995.

[3] J. Sobieszczanski-Sobieski, R. T. Haftka, Multidisciplinary aerospace design optimization: survey of recent developments, Structural Optimization, 14, 1-23, 1997.